Requirements Specification
LiU Racetrack 2017

Version 1.2

Author: Truls Nyberg
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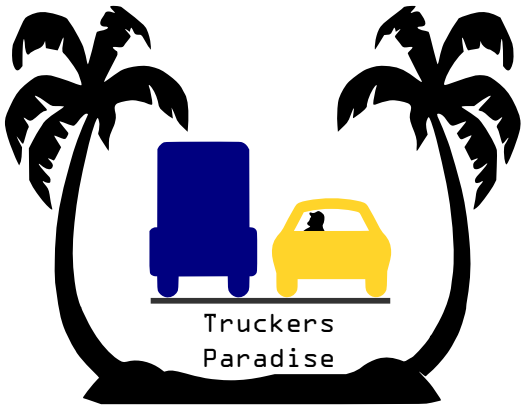

Status

Reviewed	Truls Nyberg	
Approved	Oskar Ljungqvist	

Course name:	Automatic Control - Project Course	E-mail:	axesk370@student.liu.se
Project group:	Truckers Paradise	Document responsible:	Truls Nyberg
Course code:	TSRT10	Author's E-mail:	truny887@student.liu.se
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Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2017-09-14	First draft.	Project Group	TN
0.2	2017-09-15	Second draft, updated after comments from Supervisor.	Project Group	TN
0.3	2017-10-1	Third draft, updated after comments from Orderer.	Project Group	AS
1.0	2017-10-5	Fourth draft, updated after comments from Orderer.	Project Group	JS
1.1	2017-10-5	Updated after comments from Orderer.	Project Group	JS
1.2	2017-12-04	Updated after renegotiation of requirements.	Project Group	AS

Contents

Project Identity

Group E-mail:	axesk370@student.liu.se
Homepage:	http://www.isy.liu.se/edu/projekt/tsrt10/2017/racetrack/
Orderer:	Oskar Ljungqvist, Linköping University **Phone:** +46 (0)70 577 18 68, **E-mail:** oskar.ljungqvist@liu.se
Customer:	Daniel Axehill, Linköping University **Phone:** +46 (0)13 28 40 42, **E-mail:** daniel@isy.liu.se
Course Responsible:	Daniel Axehill, Linköping University **Phone:** +46 (0)13 28 40 42, **E-mail:** daniel@isy.liu.se
Advisors:	Olov Holmer, Linköping University **Phone:**+46 (0)13 28 16 17, **E-mail:** olov.holmer@liu.se

Group Members

Name	Responsibility	Phone	E-mail (@student.liu.se)
Axel Skyttner	Project Manager	072-3410045	axesk370
Truls Nyberg	Documentation	073-0968687	truny887
Andreas Westerlund	Software	073-7421323	andve192
Oscar Törnroth	Testing	073-0640797	oscto799
Carl Rapp	Control systems	073-4065264	carra862
Gustav Sandvik	Design	073-0293777	gussa744
Martin Olsson	Motion planner, car	070-7187739	marol219
Joakim Säfdal	Motion planner, truck with semi-trailer	070-7492814	joasa165

1 Introduction

This document is a requirements specification for a CDIO-project called LiU Racetrack at Linköping University. The project is about controlling and planning radio controlled cars with the help of IR-cameras and algorithms. LiU Racetrack has been an annual project since 2011.

This year's project have three main purposes. The first purpose is to further develop the system to make it more robust and reliable. This includes that the motion planner for the car plans the whole overtaking trajectory before an overtake is initiated as well as making the collision handler in the motion planner more computationally efficient. The second purpose is to develop a motion planner for the truck with semi-trailer such that the autonomous system automatically computes a reference trajectory around the racetrack and executes this planned trajectory. The system should also be able to perform various parking manoeuvres autonomously. The third purpose is to investigate if the same controller structure as for the truck with semi-trailer can be applied for the truck with dolly-steered trailer to make it follow a precomputed trajectory around the racetrack, both in backward and forward motion.

Each requirement in this document is labeled with a priority. A priority of 1 is a requirement that needs to be fulfilled at delivery of the product. A priority of 2 is a requirement that will be implemented if there is excess time. A priority of 3 is a requirement that can be seen as suggestion for future work or be implemented if there is excess time.

The requirements are listed in tables where the first column is the unique ID-number of the requirement. Column 2 states the version of the requirement, if a requirement is renegotiated this document will be updated and the new requirement will have version "Reneg. YY-MM-DD" where reneg is an abbreviation for renegotiated and YY-MM-DD is the date when it was renegotiated. Column 3 is the actual requirement in words and column 4 states the priority of the requirement. See table 1 for example.

Table 1: An example of a requirement with its ID-number, version, description and priority.

ID-no	Version	Description	Priority
1	Original	Description of the requirement.	1
2	Reneg. YY-MM-DD	Description of the requirement.	2

2 System Overview

General requirements for the overall system architecture are listed below.

1	Reneg. 17-12-04	The system should be controlled by a program that is executed from a version controlled executable file.	1
2	Reneg. 17-12-04	The simulator should be controlled by a program that is executed from a version controlled executable file.	1
3	Reneg. 17-12-04	Choosing to use truck with semi-trailer or truck with dolly-steered semi-trailer should be accessible through the programs Graphical User Interface (GUI).	1
4	Original	With all requirements of priority 1 under sections 4, 5 and 6 fulfilled, the car and the truck with semi-trailer should be able to drive autonomously in the same direction on the track without any interruptions for 5 consecutive laps each.	1
5	Original	With all requirements of priority 1 under sections 4, 5 and 6 fulfilled, the car and the truck with semi-trailer should be able to drive autonomously in different directions on the track without any interruptions for 5 consecutive laps each.	2
6	Reneg. 17-12-04	The car should have a success rate of 80% for initiated overtaking procedures. When the planner draws a new trajectory in the GUI an overtake is considered to be initiated.	2

3 Simulator

The simulator's task is to simulate various features in the racetrack software. The requirements of the simulator are listed in the table below.

7	Original	The simulator should be able to execute without any external hardware.	1
8	Original	To be able to evaluate the software used in the reality, the simulator should be able to operate using the same modules.	1
9	Original	The simulator should have a GUI which imitates the real-world, i.e. the racetrack, cars and the truck.	1
10	Original	The simulator should visualize the generated trajectories from the planner in the GUI.	1
11	Original	The simulator should be able to create static obstacles.	1
12	Original	The simulator should be able to create dynamic obstacles.	1
13	Original	The simulator should include a motion model of the car.	2
14	Original	The simulator should be able to simulate the closed-loop system consisting of the controlled car and its low-level controller.	2
15	Original	The simulator should include a motion model of the truck with semi-trailer.	2
16	Original	The simulator should be able to simulate the closed-loop system consisting of the controlled truck with semi-trailer and its low-level controller.	2
17	Original	The simulator should be able to replay logged data from real-world experiments.	2

4 Motion planner for the car

The motion planner for the car is a Werling planner and its objective is to generate kinematically feasible and collision free reference trajectories for the car. Without obstacles on the racetrack, the Werling planner sends a predefined reference trajectory to the car's low-level trajectory tracking controller. When the reference trajectory is blocked by an obstacle, a new reference trajectory is calculated which allows the car to overtake the obstacle and avoid collision. The reference trajectory is then is sent to the car's low-level trajectory tracking controller. The requirements for this subsystem are listed in the table below.

18	Original	Planning a new trajectory in multiple Werling steps should be possible in real time.	1
19	Original	If the reference trajectory is blocked by an obstacle moving in the same direction as the car, but with a lower speed, the Werling planner should then generate a reference trajectory which overtakes the obstacle within the resolution of the Werling grid.	1
20	Original	A trajectory generated for overtaking should end back at the reference trajectory.	1
21	Original	An overtake should only be initiated if the entire overtake can be planned.	1
22	Original	If the reference trajectory is blocked by an obstacle moving in the same direction as the car and no overtake is possible, the Werling planner should then generate a trajectory that follows the obstacle.	1
23	Original	The Werling planner should be able to use the trajectory of the truck with semi-trailer when planning an overtake.	2
24	Original	The Werling planner should be able to plan a trajectory for overtaking a moving obstacle moving towards the car within the resolution of the Werling grid.	2

5 Motion planner for the truck with semi-trailer

The motion planner for the truck is a lattice planner and it is responsible of creating a kinematically feasible and collision free reference trajectory for the truck with semi-trailer. The requirements for this subsystem are listed in the table below.

25	Original	The lattice planner should be able to plan trajectories in both forward and backward motion.	1
26	Original	The truck should wait for the motion planner to generate the entire trajectory before driving.	1
27	Original	The motion planner should be able to generate a reference trajectory within 5 seconds.	1
28	Original	When the truck with semi-trailer is selected in the GUI, the motion planner should create a reference trajectory around the entire racetrack, if a feasible trajectory exists within the resolution of the planner.	1
29	Reneg. 17-12-04	If no feasible trajectory exists when planning is initiated, a trajectory should be created which takes the truck with semi-trailer as far as possible on the racetrack.	2
30	Reneg. 17-12-04	If an obstacle appears on the racetrack and blocks the generated trajectory, the truck should stop immediately and the motion planner should generate a new reference trajectory.	2
31	Reneg. 17-12-04	The motion planner should be able to plan a trajectory that ends with the truck parked at the side of the track.	2

6 Low-level controller for the truck with semi-trailer

The low-level controller for the truck with semi-trailer calculates a control signal utilizing information regarding about the truck's current state and the reference trajectory from the motion planner. A low-level controller is already implemented for the truck with semi-trailer in backward motion, the task this year is to implement a low-level controller in forward motion aswell. A longitudinal low-level controller will also be implemented so the velocity of the truck can be controlled. The requirements for the low-level controller for the truck with semi-trailer are listed in the table below.

32	Original	Use the existing model for the truck with semi-trailer described in [1] when designing the lateral low-level controller for forward driving.	1
33	Original	When the truck with semi-trailer is alone on the track it should be able to drive either forward or backward five consecutive laps without interruption. The reference trajectory around the track should be generated by the motion planner for the truck with semi-trailer.	1
34	Reneg. 17-12-04	The lateral deviation of the truck with semi-trailer should stay within 4 cm of the reference trajectory for at least 80% of the time on each lap.	1
35	Reneg. 17-12-04	The heading deviation of the truck with semi-trailer should not be greater than 5 degrees for at least 80% of the time on the lap.	1
36	Reneg. 17-12-04	The deviation in the relative angle between the semi-trailer and the truck should not be greater than 5 degrees for at least 80% of the time on the lap.	1
37	Reneg. 17-12-04	The truck with semi-trailer should have a longitudinal cruise controller.	1

7 Low-level controller for the truck with dolly-steered trailer

The truck with dolly-steered trailer is a new subsystem that will be added to the racetrack. Instead of only having the semi-trailer connected to the truck there will be a dolly in between the truck and the semi-trailer. The requirements for this subsystem are listed in the table below.

38	Original	The model for the truck with dolly-steered trailer should be based on [2].	1
39	Original	The low-level controller for the truck with dolly-steered trailer should be implemented with the same structure as the one implemented for the existing low-level controller for the truck with semi-trailer given in [1].	1
40	Original	The truck with dolly-steered trailer should be able to drive around the whole racetrack in forward motion.	1
41	Reneg. 17-12-04	The truck with dolly-steered trailer should be able to follow a straight reference trajectory when reversing without folding.	1
42	Original	The truck with dolly-steered trailer should be able to reverse through a 90-degree turn with a minimum turning radius of 25 cm.	2
43	Original	The truck with dolly-steered trailer should be able to reverse through a 180-degree turn with a minimum turning radius of 25 cm.	2
44	Original	The truck with dolly-steered trailer should be able to reverse around the whole racetrack.	3

8 Code Quality

The requirements for the code quality is listed in the table below.

45	Original	No unused code files should be delivered in the finished visual studio solution.	1
46	Reneg. 17-12-04	All new code files should include a descriptive file comment at the top.	1
47	Reneg. 17-12-04	All new code files should comply with Google C++ Style Guide.	1
48	Original	A structure for constructing new tests and unit test should be produced.	2
49	Original	Automatic tests should find build errors.	2
50	Original	New functionality should be delivered together with a unit test.	2
51	Original	New code will be code reviewed	2
52	Original	A proposal for refactoring of the structure of the parallel processes and the data communication between these should be made.	2
53	Original	The proposed refactoring of the parallel processes should be implemented.	3

9 Documentation

The Project Group shall during the project produce and deliver the documents listed below. The documents shall be delivered to the specified target group(s) at the time specified by the delivery plan in section 10. The target groups are: Project Group (PG), Customer (CU), Orderer (OR), Supervisor (SV) and Course Responsible (CR).

Document	Description	Target group(s)
Requirement Specification	Specification of the requirements that should be fulfilled at the deliveries of the project.	PG, CU, OR
Project Plan	Project overview and execution.	PG, SV, OR
Time Plan	Describes how the available time should be distributed among the different activities.	PG, SV, OR
Design Specification	A brief description of the system fulfilling the required specifications.	PG, SV, OR
Test Plan	Describes the tests to be made in order to verify the required specifications of the system.	PG, SV, OR
Test Protocol	The results of the tests in the test plan.	CU, OR
User Manual	Instructions of how to use the system.	CU
Technical Documentation	A detailed description of the entire system.	CU
Homepage	Public documentation of the project.	SV, CU
Poster	Summary of the system for advertising purpose.	CU
Advertising Film	Public advertising in video format.	CU
After Study	Summery and analysis of the project.	CR
Meeting Protocol	Notes from project meetings.	PG

10 Delivery

The Project Group shall follow the delivery plan bellow. Some of the deliveries are connected to a specific date defined by a Tollgate (TG), where TG 2 is at 2017-09-18, TG 3 is at 2017-09-25, TG 4 is at 2017-11-13, TG 5 is at 2017-12-04 and TG 6 is at 2017-12-18.

54	Original	Every week, a time report shall be delivered to the Orderer (OR)	1
55	Original	Every week, a status report shall be delivered to the Orderer (OR) and the customer (CU).	1
56	Original	At TG 2, the Requirements Specification shall be delivered.	1
57	Original	At TG 2, the Project Plan shall be delivered.	1
58	Original	At TG 2, the Time Plan shall be delivered	1
59	Original	At TG 2, a draft of the Design Specification shall be delivered.	1
60	Original	At TG 3, the Design Specification shall be delivered.	1
61	Original	At TG 3, the Test Plan shall be delivered.	1
62	Original	At TG 4, a partial delivery of the system shall be presented.	1
63	Original	At TG 5, the finished system shall be delivered.	1
64	Original	At TG 5, the Test Protocol shall be delivered.	1
65	Original	At TG 5, the User Manual shall be delivered.	1
66	Original	At TG 5, a presentation of the finished system shall be performed.	1
67	Original	At TG 6, the Technical Specification shall be delivered.	1
68	Original	At TG 6, the After Study shall be delivered.	1
69	Original	At TG 6, the Poster shall be delivered.	1
70	Original	At TG 6, the Homepage shall be delivered.	1
71	Original	At TG 6, the Advertising Film shall be delivered.	1

11 Finance

The requirements for the finance of the project are listed in the table below.

72	Original	Each team member has maximum 240 hours to spend on the project.	1
73	Original	The total tutoring time is 40 hours	1

References

[1] Marcus Almen. Technical documentation liu racetrack 2016, 2016.

[2] Anders Helmersson Oskar Ljungqvist, Daniel Axehill. Path following control for a reversing general 2-trailer system. 2016.